

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 034136-022	FOR FURTHER ACTION <small>see Form PCT/ISA/220 as well as, where applicable, item 5 below.</small>	
International application No. PCT/US05/10214	International filing date (<i>day/month/year</i>) 25 March 2005 (25.03.2005)	(Earliest) Priority Date (<i>day/month/year</i>) 26 March 2004 (26.03.2004)
Applicant LUNA INNOVATIONS INCORPORATED		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 1 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the Report

a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ The international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (See Box No. II)

3. ☐ **Unity of invention is lacking** (See Box No. III)

4. With regard to the **title**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

a. the figure of the **drawings** to be published with the abstract is Figure No. _____

☐ as suggested by the applicant.

☐ as selected by this Authority, because the applicant failed to suggest a figure.

☐ as selected by this Authority, because this figure better characterizes the invention.

b. ☒ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US05/10214

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H01L 31/0256, 51/00

US CL : 136/263; 257/53

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 136/263; 257/53

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Google search on inventors and fullerenes or trimetaspheres in solar/photovoltaic/photoconductive devices

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6,174,780 B1 (Robinson) 16 January 2001 (16.01.2001), entire document.	13 and 15-18
Y	US 2002/0189666 A1 (Forrest et al) 19 December 2002 (19.12.2002), entire document.	1-39
Y	Trulove, S. "Filled buckyballs - diamonds from soot", article from website http://www.research.vt.edu/resmag/2002winter/buckyballs.html , 9 March 2002 (09.03.2002), available at www.archive.org . Entire document.	1-39



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A"	document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"B"	earlier application or patent published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

06 July 2005 (06.07.2005)

Date of mailing of the international search report

19 JUL 2005

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US
Commissioner for Patents
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Alexandria, Virginia 22313-1450

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J. W. Barton
for

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
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PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

Applicant's or agent's file reference 034136-022		Date of mailing (day/month/year) 19 JUL 2005
International application No. PCT/US05/10214		FOR FURTHER ACTION See paragraph 2 below
International filing date (day/month/year) 25 March 2005 (25.03.2005)	Priority date (day/month/year) 26 March 2004 (26.03.2004)	
International Patent Classification (IPC) or both national classification and IPC IPC(7): H01L 31/0256, 51/00 and US Cl.: 136/263; 257/53		
Applicant LUNA INNOVATIONS INCORPORATED		

1. This opinion contains indications relating to the following items:

- | | | |
|-------------------------------------|--------------|--|
| <input checked="" type="checkbox"/> | Box No. I | Basis of the opinion |
| <input type="checkbox"/> | Box No. II | Priority |
| <input type="checkbox"/> | Box No. III | Non-establishment of opinion with regard to novelty, inventive step and industrial applicability |
| <input type="checkbox"/> | Box No. IV | Lack of unity of invention |
| <input checked="" type="checkbox"/> | Box No. V | Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement |
| <input type="checkbox"/> | Box No. VI | Certain documents cited |
| <input checked="" type="checkbox"/> | Box No. VII | Certain defects in the international application |
| <input type="checkbox"/> | Box No. VIII | Certain observations on the international application |

2. FURTHER ACTION

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA/ US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (703) 305-3230	Authorized officer Jeffrey T. Barton Telephone No. (571)272-1307
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**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

PCT/US05/10214

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ This opinion has been established on the basis of a translation from the original language into the following language _____, which is the language of a translation furnished for the purposes of international search (under Rules 12.3 and 23.1(b)).

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application and necessary to the claimed invention, this opinion has been established on the basis of:

a. type of material

☐ a sequence listing

☐ table(s) related to the sequence listing

b. format of material

☐ in written format

☐ in computer readable form

c. time of filing/furnishing

☐ contained in international application as filed.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

**WRITTEN OPINION OF THE
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Box No. V Reasoned statement under Rule 43 bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims <u>1-12, 14, and 19-39</u>	YES
	Claims <u>13 and 15-18</u>	NO
Inventive step (IS)	Claims <u>NONE</u>	YES
	Claims <u>1-39</u>	NO
Industrial applicability (IA)	Claims <u>1-39</u>	YES
	Claims <u>NONE</u>	NO

2. Citations and explanations:

Please See Continuation Sheet

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

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Box No. VII Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

Claims 2, 14, and 28 are objected to under PCT Rule 66.2(a)(iii) as containing the following defect(s) in the form or contents thereof: the limitation "wherein the absorber and trimetasphere are a heterojunction" is inaccurate. Rewording, such as "wherein the absorber and trimetasphere form a heterojunction" is suggested.

Claims 3, 15, and 29 are objected to under PCT Rule 66.2(a)(iii) as containing the following defect(s) in the form or contents thereof: the limitation "wherein the absorber and trimetasphere are a blended junction" is inaccurate. Rewording, such as "wherein the absorber and trimetasphere form a blended junction" is suggested.

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Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

V. 2. Citations and Explanations:

Claims 13 and 15-18 lack novelty under PCT Article 33(2) as being anticipated by Robinson.

Regarding claim 13, Robinson discloses an electrical circuit (e.g. Figure 3; Column 7, lines 46-58) comprising an absorber of incident electromagnetic radiation (Polysilicon layer 34); a trimetasphere-containing material in electron-transferring contact with the absorber (High dielectric film 31; Column 7, lines 6-18 and 48-51; Column 3, lines 42-55; Column 4, lines 29-47); an anode (e.g. n-type region 32); a cathode (e.g. polysilicon region 34); and a current path from anode to cathode (Between layers 34 and 32, through layer 31; although the circuit is a capacitor, a finite leakage current will inherently be present upon voltage application to the electrodes). Robinson discusses metal oxide dielectrics encapsulated in fullerenes in the citations given above, which reads on "trimetasphere" as broadly described in the specification at Page 4, lines 5-7.

Regarding claim 15, the absorber and trimetasphere layers will not be perfectly even, leading inevitably to a transition region of mixed absorber/trimetasphere composition. This structure reads on "blended".

Regarding claim 16, Robinson discloses the anode (e.g. region 32) being in contact with the trimetasphere layer (31). (Figure 3)

Regarding claim 17, Robinson discloses the cathode (e.g. polysilicon 34) being the absorber, which would inherently meet the electrical contact requirement. (i.e. the material is in electrical contact with itself)

Regarding claim 18, Robinson discloses the trimetasphere being a carbon-cage structure with an interior volume, encapsulating one or more metal atoms complexed with a non-carbon heteroatom. (Column 7, lines 6-18 and 48-51; Column 3, lines 42-55; Column 4, lines 29-47) Encapsulated metal oxides meet the limitations.

Claims 1-39 lack an inventive step under PCT Article 33(3) as being obvious over Forrest et al in view of Trulove.

Regarding claim 1, Forrest et al disclose a photovoltaic device for conversion of incident electromagnetic radiation to electricity, comprising: an absorber of incident electromagnetic radiation (Copper phthalocyanine (CuPc); Figure 1 shows a bandgap of 1.7 eV, which corresponds to absorption onset at 730 nm; Paragraph 0030); a fullerene electron transfer layer in electron transferring contact with the absorber (Paragraphs 0027-0030); an anode in contact with the fullerene layer (Paragraphs 0032 and 0033; Paragraph 0056 describes the laminate in its first sentence, which includes an Al electrode in contact with the fullerene layer); and a cathode in electrical contact with the absorber (Paragraph 0033)

Regarding claim 13, the structure described above as relevant to claim 1 also reads on the same limitations. Additionally, Forrest et al disclose measuring a short-circuit current of one of their cells (Figure 3 inset; Paragraph 0024), such a short circuit (i.e. no load) provides a current path between the electrodes.

Regarding claim 27, Forrest et al disclose a method of converting incident radiation to electricity, comprising: absorbing the radiation to produce an electron-hole pair (Radiation absorption described in paragraphs 0008 and 0043, this is inherent in solar cells); transferring an electron in the LUMO of the absorber across a bandgap to the fullerene-containing layer (Figure 1; process is described in Background section at paragraphs 0008-0013; since the fullerene layer is the "acceptor type" ETL (Paragraphs 0016 and 0028), excited electrons would be transferred from the hole transport layer to the fullerene layer in operation); injecting an electron from the fullerene layer into the anode (Figure 1) and transferring a hole in the HOMO of the CuPc layer into the cathode; and completing a circuit between the anode and cathode. (These final steps are inherent in the operation of this cell - the hole and electron transport are necessary for functioning of the cell, and completing the circuit is the only way to extract power from the cell, which is shown in Figures 2-4)

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Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Regarding claims 2, 14, and 28, Forrest discloses the boundary between the fullerene layer and absorber (CuPc) being a heterojunction. (Paragraph 0030)

Regarding claims 3, 15, and 29, the absorber and fullerene layers will not be perfectly even, leading inevitably to a transition region of mixed absorber/fullerene composition. This structure reads on "blended".

Regarding claims 16 and 17, these limitations were addressed in addressing claim 1 above.

Regarding claim 37, the bandgap of CuPc is 1.7 eV, which corresponds to an absorption onset of 730 nm, which falls in the visible spectrum. (red)

In addition, Forrest suggests the use of layers of modified fullerenes, with the only criterion being that they function as efficient electron transfer layers.

Forrest does not explicitly disclose using trimetaspheres in the electron transfer layers.

Trulove discloses applications for trimetaspheres (Pages 5-8), including explicit suggestion that current fullerene-containing organic photovoltaic devices would be improved by using trimetaspheres instead. (Page 6, 2nd column, 4th full paragraph)

Regarding claims 4, 18, and 30, Trulove discloses the trimetasphere including a carbon cage structure with an interior volume, encapsulating metal ions complexed with a non-carbon heteroatom. (Page 2, 2nd column, 1st full paragraph; Page 4, 1st column, 2nd full paragraph - Page 6, 1st column, 1st full paragraph)

Regarding claims 5, 6, 19, 20, 31, and 32, Trulove discloses the trimetasphere having this general formula ($n=0$), where N is nitrogen. (Page 2, 2nd column, 1st full paragraph; Page 4, 1st column, 2nd full paragraph - Page 6, 1st column, 1st full paragraph)

Regarding claims 7-10, 21-24, and 33-36, Trulove discloses A or X being scandium. (with $n=0$ or $n=3$, accordingly) (Paragraph bridging the 1st columns of pages 4 and 5, last sentence)

Regarding claims 11, 12, 25, 26, 38, and 39, Trulove discloses this structure, which includes a heteroatom (nitrogen). (Page 4, 1st column, 2nd full paragraph - Page 6, 1st column, 1st full paragraph)

It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the solar cell of Forrest by replacing the fullerene molecules with trimetaspheres, as suggested by Trulove, because Trulove suggested that it was believed that this would result in a five-to-tenfold increase in cell efficiency. (Page 6, 2nd column, 4th full paragraph)

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under Article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the *PCT Applicant's Guide*, a publication of WIPO.

In these Notes, "Article," "Rule" and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions, respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only.

What parts of the international application may be amended ?

Under Article 19, only the claims may be amended

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Preliminary Examining Authority

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When ? Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments ?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How ? Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments ?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.